

Complementary-pair dc/dc converter simultaneously doubles, inverts supply voltage

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 The circuit in this Design Idea uses an intrinsic property of collector voltages in one-transformer push-pull dc/dc converters: They have a swing of twice the supply voltage. When you implement these circuits with an NPN device, the collector swings from 0V to twice the supply-rail voltage. When you use PNP devices, the collector voltage swings from V_{CC} to an equal amplitude but negative V_{CC} (Reference 1). In this circuit, a complementary pair of transistors, simultaneously imple-

menting a voltage doubler and a negative-voltage source, drives the two windings of the transformer.

One of the windings of transformer T_1 connects to ground, driven by PNP transistor Q_1 from V_{CC} (Figure 1). The other winding of T_1 connects to V_{CC} , and NPN transistor Q_3 drives the lower end to ground. Q_2 and Q_4 drive Q_1 and Q_3 , respectively. The collectors of Q_3 and Q_1 through resistors R_4 and R_3 provide cross-coupled drives to Q_2 and Q_4 . R_1 and R_2 form the collector loads for Q_2

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and Q_4 . D_1 and D_4 prevent the reverse breakdown of Q_1 and Q_3 . The drive configuration and the transformer's winding polarity provide regenerative feedback and self-oscillation so that the transformer alternates between positive and negative saturation, inducing voltages to drive transistors Q_1 and Q_3 alternately on and off.

A square wave with an amplitude twice V_{CC} is generated at the collector of Q_1 , which swings nominally from V_{CC} to the equal but negative output voltage. Simultaneously, a square wave with an amplitude twice the supply-rail voltage is generated at the collector of Q_3 , which swings nominally from 0V to twice the supply-rail voltage.

D_2 and C_2 provide half-wave rectification and filtering of the Q_1 collector waveform generating the negative voltage output. Half-wave rectification and filtering of the Q_3 collector waveform using D_3 and C_3 generate the doubler's output.

T_1 is 200 turns of bifilar AWG 37 enameled wire

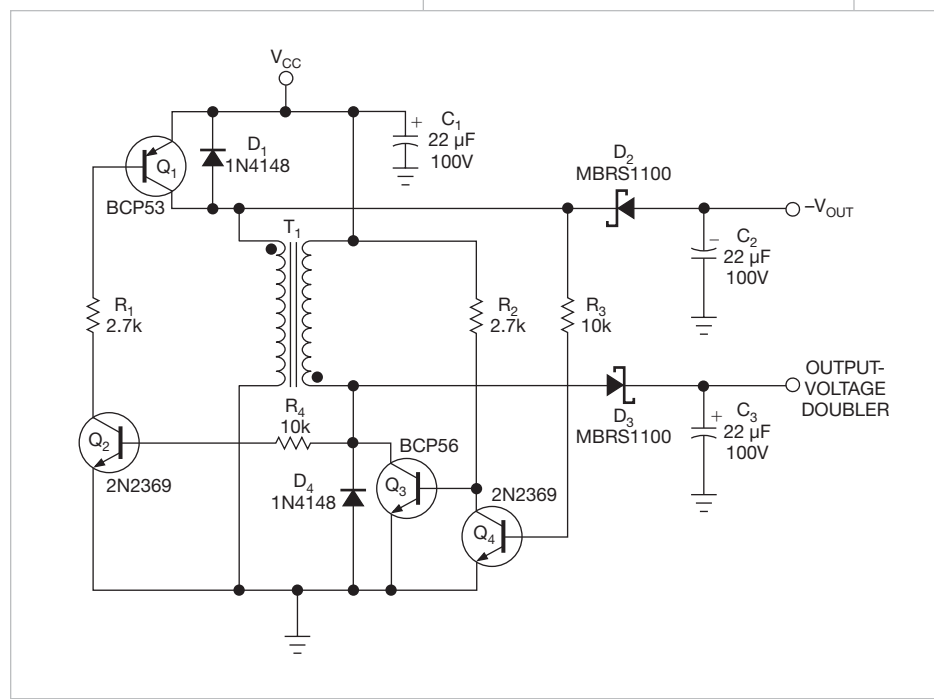


Figure 1 Cross-coupled regeneration drives switching transistors Q_1 and Q_3 and the windings of the transformer. The resulting voltage swings at their collectors are rectified to twice the positive and the negative power-supply rails.

TABLE 1 EXPERIMENTAL RESULTS

Input voltage (V)	Input current (mA)	Frequency (kHz)	Voltage doubler (V)	Current doubler (mA)	Negative voltage (V)	Negative current (mA)	Input power (W)	Output power (W)	Efficiency (%)
5	253	2.1	7.68	81.7	-3.41	-72.5	1.27	0.87	69
9.97	360	4.05	17.33	115.5	-8.65	-86.5	3.59	2.75	76.6
15	420	6.02	27.2	136	-13.58	-90.5	6.3	4.93	78.2
19.4	400	7.37	34.9	145.4	-18.33	-61.1	7.76	6.19	79.8
25	340	10.47	48.5	97	-23.8	-79.3	8.5	6.59	77.5
30	410	12.07	56.5	113	-27.6	-92	12.3	8.92	72.5

wound 1-to-1 on a ferrite toroid core (references 2 and 3). Table 1 shows the experimental results with the voltage doubler and negative-voltage-generation circuit operating over an input voltage of 5 to 30V, demonstrating operation over a wide input volt-

age range and providing power at both outputs simultaneously at moderate efficiency. **EDN**

REFERENCES

1 Raman, Ajoy, "Voltage doubler uses inherent features of push-pull dc/dc

converter," *EDN*, Aug 16, 2007, pg 72, <http://bit.ly/GTlveF>.

2 "T503125," Ceramic Magnetics Inc, <http://bit.ly/L3FzeW>.

3 MN60 manganese-zinc material specs, Ceramic Magnetics Inc, <http://bit.ly/KoyO4Y>.

Adjust power-efficient LED switch to any light intensity

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 You can use an LED as a photoelectric sensor. A previous Design Idea shows that such a switch is highly power-efficient, consuming almost no power (Reference 1). However, you cannot adjust that configuration to switch at the desired light intensity. You can adjust the circuit in this Design Idea to any threshold level of light intensity necessary to maintain the on state of the photoelectric switch while retaining almost the same power efficiency of the original circuit (Figure 1).

Illuminating the reverse-biased green LED with ambient light causes the small current that flows through the LED to form the base current of the BC549 NPN transistor, which is amplified and passed on to the base of the BC177 PNP transistor. A magnified version of this current flows through the emitter of the BC177. The voltage drop across the emitter resistor depends on its value and the current flowing through it, which in turn determines the voltage drop across the CE terminals of the BC549.

By adjusting the value of the series emitter resistor you can set a voltage

corresponding to logic zero of a CMOS gate for any desired intensity of light falling on the green LED. This intensity depends heavily on the response of the green LED and the current gains of the

two transistors, so you select the resistor value by shorting out combinations of the series string of resistors and use the 10-M Ω potentiometer as a fine adjustment. Once you find a suitable value,

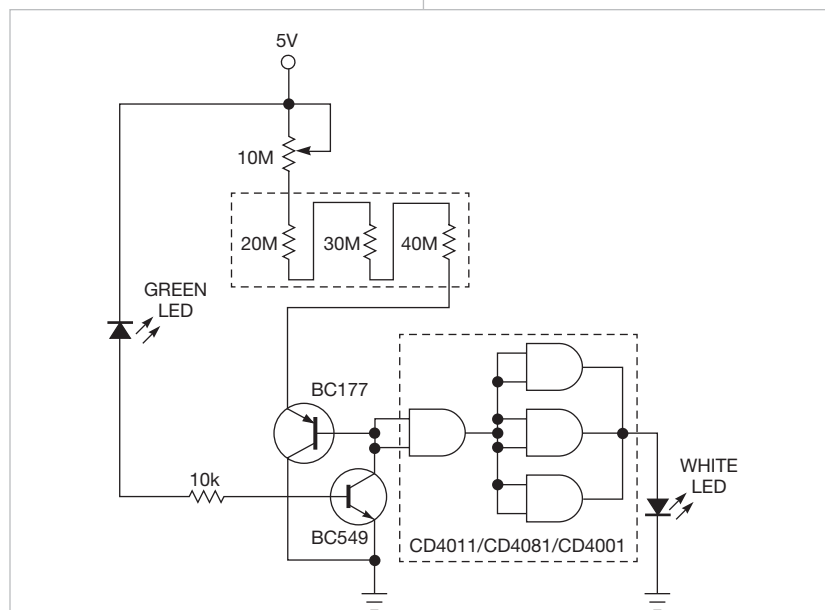


Figure 1 The photocurrent through the green LED amplifies to CMOS-logic levels to turn on the white LED when ambient light falls.

you can remove the unused resistors from your circuit.

When the ambient light intensity falls below this level, both the base current of the BC549 and the current through the emitter series resistors decrease. This decrease raises the input voltage at the CD4011 logic gate higher than the CMOS switching threshold. The typical gate sourcing current at a 3V output is approximately

3 to 4 mA per gate; running three gates in parallel delivers approximately 10 mA to the white LED. You can use inverting or noninverting gates for the same result. The circuit still retains its power efficiency because the required series-resistor values normally exceed 10 M Ω .

You can check a green LED's suitability for use as a photodiode by measuring the voltage drop across the LED

with a 200-mV digital multimeter. If the LED is suitable as a photoelectric sensor, you will see a voltage of 0.3 to 1 mV across it, and this voltage changes with the intensity of light falling on the LED. **EDN**

REFERENCE

■ Baddi, Raju R, "Use LEDs as photo-diodes," *EDN*, Nov 18, 2010, pg 45, <http://bit.ly/HaLtFu>.

Obtain a gain of 450 from one vacuum tube

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➡ A direct-conversion radio receiver required an audio gain of 450 from a pentode vacuum tube. A pentode has a high transconductance—that is, the ratio of the change in plate current to the change of the control grid voltage that caused it. To get high gain, however, it needs a high load impedance. RF applications with pentodes often used LC-tuned circuits in their plate loads in which the impedance at resonance and, therefore, the gain is high. It is typically impossible to implement a high load impedance using an untuned circuit because of the dc requirements of the tube.

RF APPLICATIONS WITH PENTODES OFTEN USED LC-TUNED CIRCUITS IN THEIR PLATE LOADS.

For instance, a 6AU6 pentode vacuum tube needs a quiescent plate current of approximately 5 mA (**Figure 1**). If the quiescent dc plate voltage is to be 60V, the load resistance must be no more than 12 k Ω . The 0.5-M Ω plate resistance of the tube and the 1-M Ω load of the next stage are negligible with respect to the 12-k Ω load. With a transconductance of 3900 siemens, those requirements demand an audio gain of 45. You can easily achieve this gain with a triode tube.

To get a high load impedance with an untuned plate circuit, you can use a transistor current source for the tube (**Figure 2**). The transistor has no gain but functions as an active load for the tube and supplies the 5-mA plate current. You adjust the 500 Ω potentiometer to obtain 60V dc at the plate. The gain of the circuit is approximately 450. This gain implies a 150-k Ω load impedance that the transistor supplies in parallel with the plate resistance and the resistance of the next stage. Alternatively, you can use two triode tube circuits in series, each having a gain of 21. **EDN**

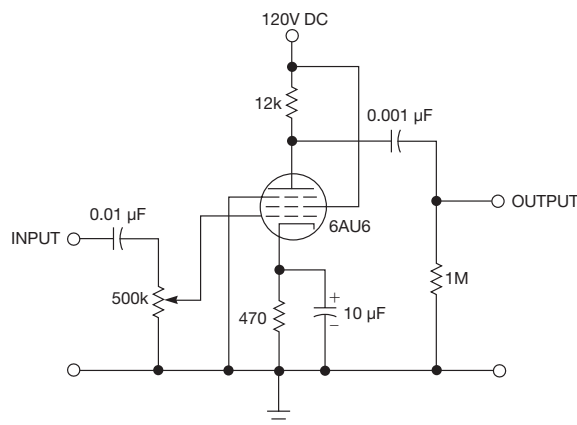


Figure 1 A 6AU6 pentode vacuum tube needs a quiescent plate current of approximately 5 mA.

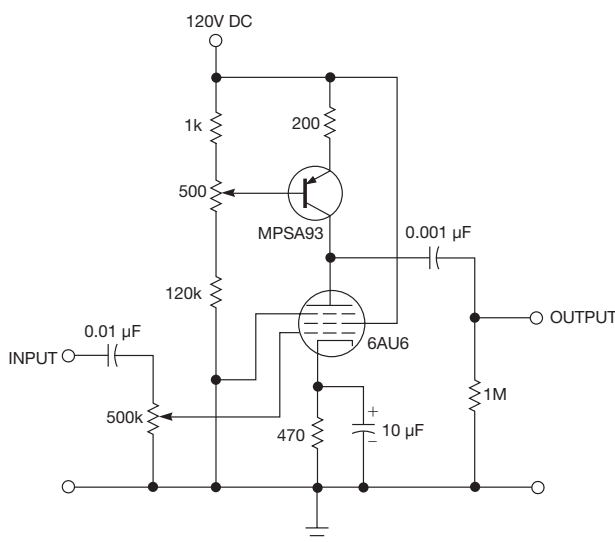


Figure 2 To get a high load impedance with an untuned plate circuit, you can use a transistor current source for the tube.

Probing system lets you test digital ICs

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 This Design Idea describes a simple yet powerful handheld probe that you can use as both a logic probe and a pulse generator either individually or simultaneously. This feature makes the probe useful for testing DIP digital ICs, such as gates, flip-flops, and counters, using a socketed fixture with three-post jumpers to connect each pin to logic high or logic low or to 5V or ground. Three pushbutton switches, two dual-color LEDs, and two probe tips are built

into a plastic cylinder, such as an empty 20g-or-larger glue-stick tube. The generator's probe tip hooks to fit onto the test fixture's jumper pins and mounts onto a spring, such as those in retractable ball-point pens, for flexibility, and it allows the logic-probe tip to move to the output under test. Two of the pushbutton switches set the generator's quiescent state for a high output or a low output. The third switch briefly single-pulses the output to the opposite state. If the switch

is pressed for longer than 2 seconds, the output produces a pulse train.

IC_{1A}, an NE556, is a 2-sec monostable circuit, which triggers a 1-msec-pulse-generator circuit employing gate G₁, resistor R₁, and capacitor C₁ (Figure 1a). G₄ buffers the circuit. The output of the monostable circuit also passes through G₂ and G₃ to mask the output of the astable component, IC_{1B}, an NE556 that provides the pulse train. To prevent any spurious pulse from reaching output Probe A when switch S₁ is not depressed, keep IC_{1B} deactivated by applying a low voltage to its reset Pin 4 through transistor Q₁, whose biasing a 0.68-μF capacitor further guards.

When you press switch S₁ for a short

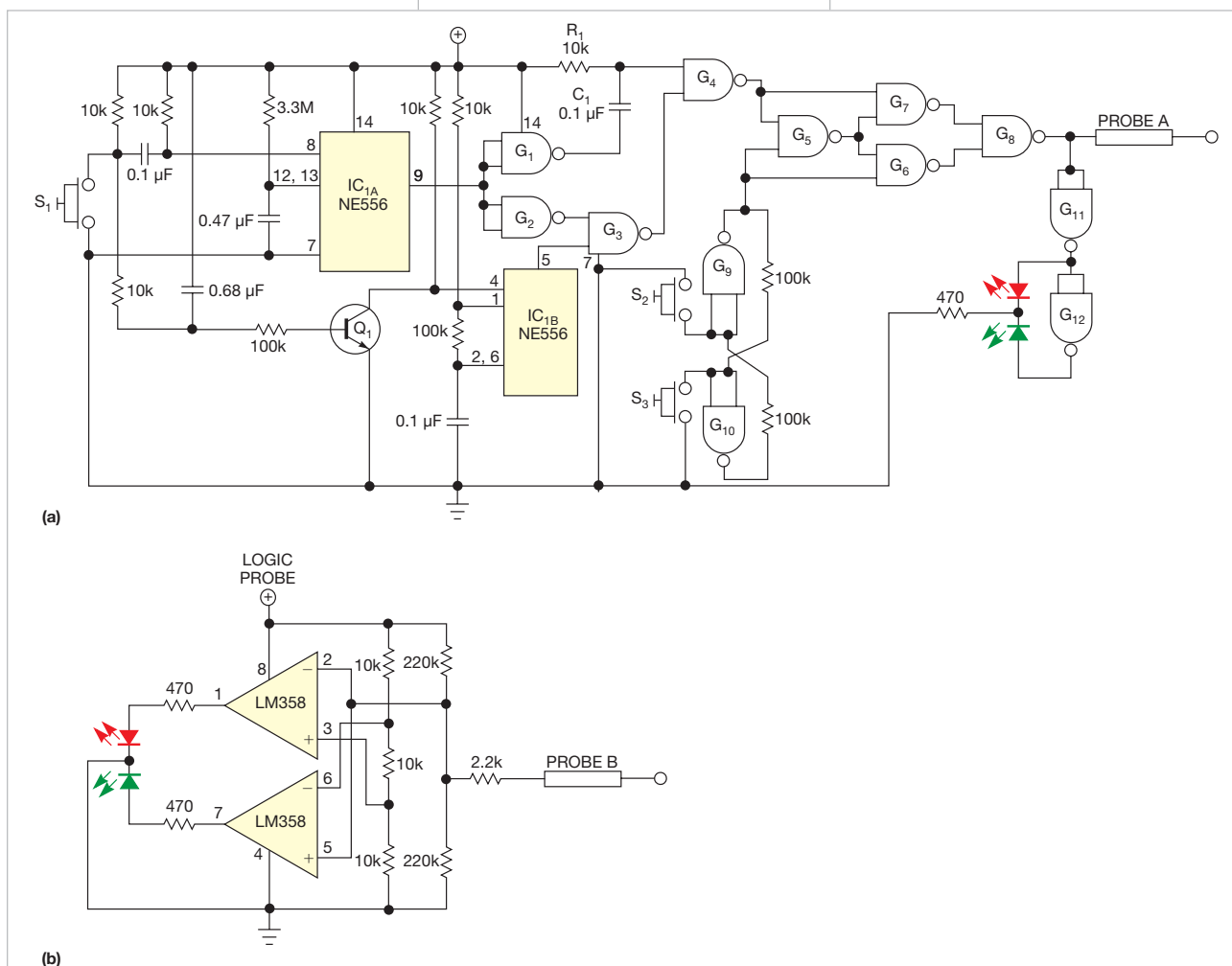


Figure 1 This circuit combines analog and digital functions. Probe A is the pulse-generator probe, and probe B is the logic probe (a). Although not shown, a 100-μF capacitor should be connected between the supply and ground. Red LEDs indicate logic zero, and green LEDs display logic one (b).

time, IC_{1A} fires and produces a high output for approximately 2 sec. The 1-msec pulse from G₁, R₁, C₁, and G₄ reaches the pulse Probe A through the XOR function comprising G₅ through G₈, and

the output of the astable IC_{1B} is masked at G₃ from reaching the XOR. If you depress switch S₁ for longer than 2 sec, the monostable IC_{1A} times out. This action unmask G₃ and allows the 70-Hz

oscillation from IC_{1B} to reach the XOR.

G₉ and G₁₀ form a bistable circuit, which “remembers” the most recently pressed S₂ or S₃ switch and controls the inverting and noninverting operation of the XOR function. G₁₁ and G₁₂ together drive the dual-color LED to indicate the pulse generator’s polarity. Red indicates that Probe A’s output is mainly logic zero, with the single 1-msec pulse a logic high. Green indicates the opposite.

The LM358 acts as a window-detector logic probe (**Figure 1b**). With the values in the **figure**, the red LED lights at Probe B voltages of less than 35% of the supply voltage, and the green LED lights at voltages greater than 65% of the supply voltage. Neither LED lights between these voltages. You may wish to adjust the resistor network to reduce the lower threshold to include the transistor-transistor-logic zero of less than 0.8V.

If you use CD4011 quad NAND gates, you can externally power the probe at 4.5 to 15V. Using a CD4093 Schmitt-trigger quad NAND for G₁ through G₄ ensures no spurious oscillations as a result of the slow voltage rise at timing capacitor C₁. If your design requires a higher-current generator drive, you can add a pair of NPN and PNP boost transistors to the output.

Figure 2 shows a jig for testing the digital ICs. You configure the 16-pin DIP socket for the device under test with an array of triple-post headers and push-on jumpers. You can connect any pin directly or through a resistor to power or ground to configure power or logic levels. The resistors can be any suitable value; approximately 2 k Ω is appropriate. To set a TTL low, the pin must connect directly to ground. To inject a signal, hook the flexible spring-mounted generator, Probe A (**Figure 3**), onto the appropriate input post and then move logic Probe B to the corresponding output post or pin. To see a suggested perf-board layout, go to www.edn.com/4374947. **EDN**

REFERENCES

- 1 Baddi, Raju, “Logic probe uses six transistors,” *EDN*, Dec 15, 2010, pg 46, <http://bit.ly/n24oau>.
- 2 Rentyuk, Vladimir, “Logic probe uses two comparators,” *EDN*, Aug 25, 2011, pg 54, <http://bit.ly/wtuKgi>.

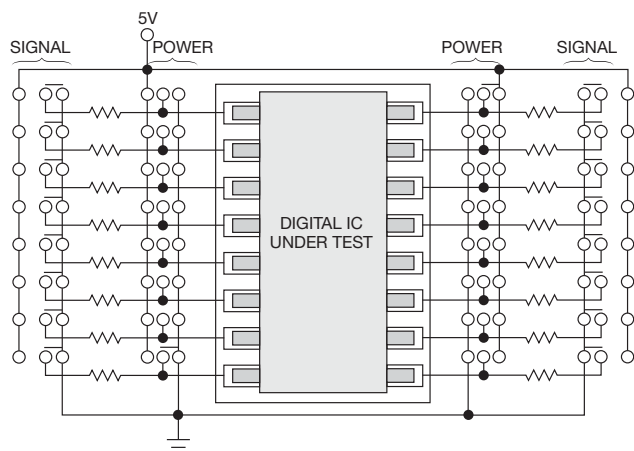


Figure 2 Program this test jig with header posts and jumpers for the IC under test.

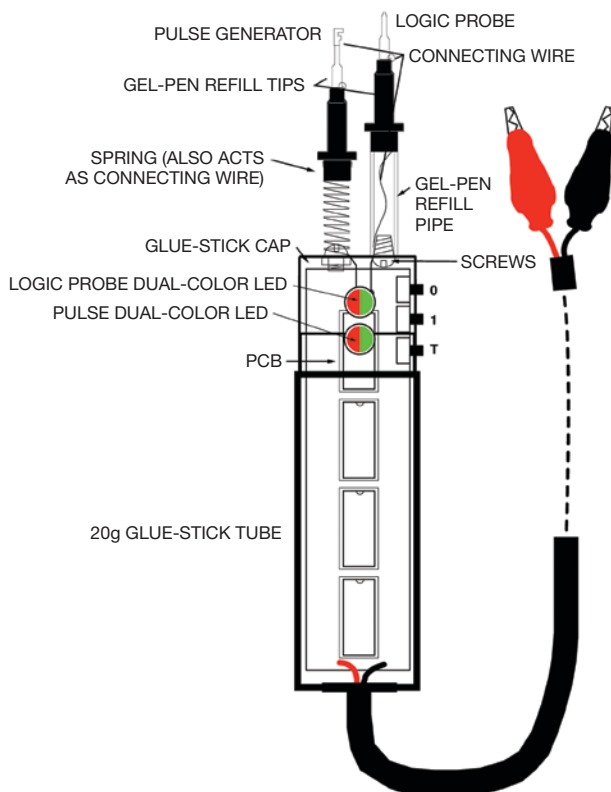


Figure 3 To inject a signal, hook the flexible spring-mounted generator, Probe A, onto the appropriate input post and then move logic Probe B to the corresponding output post or pin.